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THE PROBLEM OF TELEVISION RELAY SYSTEMS IN USSR

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/Figures referred to are appended./

The 19th Party Congress set forth the problem of further development of television in the USSR. Most of the technical problems relating to television equipment are being solved by Soviet scientists and engineers. However, difficulties are being encountered in solving some other very important problems. One of these is the problem of transmitting television over great distances and in this paper we will consider some possible methods for solving this distance problem.

It would seem easiest to transmit television programs over great distances by means of coaxial cable or wave guide. However, this method would be one of the most expensive because it would be necessary to construct many amplifying relay points and television transmitters along such lines. For example, in order to transmit programs a distance of [illegible],000 km, it would be necessary to install about [illegible] amplifying units along the route.

At the present time, it seems most economical to use radio relay lines (Figure 1) for intercity transmission of television programs. Radio relay lines, which were proposed in the USSR in [illegible] by Prof V. I. Kovalenkov (Patent No [illegible]), are widely used for communications purposes. In accordance with the decrees of the 19th Party Congress, the radio relay lines will be developed extensively. However, in a country as vast as the Soviet Union, the problem cannot be solved by this method alone. One can easily calculate that about 1,000 radio transmitters would be required to serve the European USSR alone by radio relay lines. In addition, the picture distortion would increase as the chain of radio relay stations became longer.

The number of transmitters required could be reduced considerably by increasing the heights of the transmitting and receiving antennas at the relay points, but the possibilities of constructing very high towers for television antennas are limited, considering the status of modern construction engineering. The height of the receiving antennas does not exceed 8-10 m for quite understandable technical reasons. Consequently, the radius of operation of a television center could be increased in practice only in increasing the height of its transmitting antenna. A graph of the theoretical dependency of the television center's radius of action upon the height of the transmitting antenna, with consideration for the actual heights of receiving antennas (8-10 m), is given in Figure 2. As this graph shows, in order to increase the radius of operation of an ultrashort-wave transmitter ten-fold, it would be necessary to increase the transmitting antenna height almost 275 times.

Nevertheless, the development of radio relay lines is the first and most practical solution to the distance problem in television. This method is also of considerable interest because it opens up a broad field of activity for radio clubs.

In 1937, Prof P. V. Shmakov proposed that aircraft be used as "flying supports" for television antennas. He suggested the development of a chain of radio relay stations to be lifted on aircraft to a height of about 9-10 km; the distance between individual stations would be about 500-600 km (Figure 3). It is easily seen that in order to provide television broadcasts to the European USSR, for example, about 20 aircraft would have to be kept continually in the air, i.e., one aircraft radio relay installation could replace 40-50 surface stations.

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At first glance, Professor Shmakov's proposal is very appealing. However, more careful inspection shows that it suffers from a number of defects, whose removal would require considerable monetary expenditures and complex engineering solutions. These defects include: (1) the difficulty of establishing directional communications between aircraft flying great distances apart, so that the linking airplanes would have to have powerful transmitters; (2) the great dependency of the system upon the weather -- if an airplane at one point of the system could not fly, the operation of all the remaining links of the system would be disrupted; and (3) the considerable expense connected with the operation of the aircraft.

Nevertheless, Shmakov's project deserves consideration and a final conclusion as to its feasibility can be made only after the most careful study from the engineering economics standpoint.

In the search for methods of solving the distance problem, scientists have turned their attention to the possibility of using the reflection of ultrashort waves from various conducting surfaces, e.g., the moon. According to this possibility, the signals of an ultrashort-wave television station are directed at the surface of the moon, and the reflected waves return to the earth in a wide cone. The authors of this proposal feel that the transmission of one television signal could in this manner be received at any point of one hemisphere (Figure 4).

Is this plan feasible? The physical possibility of receiving a radio impulse reflected by the moon has been demonstrated by radar experiments. However, this does not mean that it is practical to receive television signals reflected from the moon. As has been stated, the distance problem was encountered in television because of the need for transmitting a very wide band of frequencies for the picture. An increase in the frequency band to be transmitted entails an increase of transmitter power. In a report read in May 1953 at the All-Union Session of VNORIE (the All-Union Scientific and Technical Society of Radio Engineering and Electric Communications), Prof S. I. Katayev showed that in order to obtain a moon-reflected signal in which reception of television signals would be possible, one would have to build a transmitter whose antenna power would be of the order of 10 billion kw. The energy required to supply such a transmitter would be greater than that produced by 5,000 Kuybyshev hydroelectric power stations.

A marked compression of the frequency band would make it possible to reduce the power required considerably. For example, a power of only 2,500 kw would be required to transmit a band about 25 cps wide. Now, the frequency band of the signals from a single picture element does not exceed 25 cps. With this in mind, Professor Katayev suggested that it might be possible to eliminate the sequential transmission of picture elements by replacing it with a system involving simultaneous transmission of signals from each picture element on an independent carrier frequency. However, insurmountable technical difficulties are encountered in the practical development of such a system.

The picture is divided into approximately 500,000 elements. Consequently, 500,000 transmitters, each having a power of 2,500 kw, would be required for simultaneous transmission of all these elements. The total power of these transmitters would be slightly less than in the case of element-by-element transmission of the picture, but it is impractical to develop a transmitting installation to work on 500,000 carriers.

Therefore, Professor Katayev suggested that simultaneous transmission be limited to the lines instead of to the elements. In this case, scanning of each line could be done in the ordinary way, i.e., element-by-element. The frequency band of signals from each line to be transmitted would be increased and, consequently, the power of each transmitter would have to be increased. But then the total number of transmitters could be reduced from 500,000 to 625. The total power required in this system would be slightly greater than that required for simultaneous transmission of all picture elements.

Very complex and expensive commutation equipment would have to be developed
for both the transmitting and receiving units in order to transmit all lines
simultaneously. Present television receivers could not receive such transmis-
sions without adapters. Each city and town would have to have special relay
points whose cost and complexity would greatly exceed that of ordinary radio re-
lay stations.

However, in our opinion, the problem of obtaining high powers is not the
decisive factor in evaluating the feasibility of this plan. Instead, we must
bear in mind that the surface of the moon is not ideally smooth; it is marked
by high mountains (reaching 9,000 m), mountain chains, valleys, etc. Because
of this, signals arriving at the moon will not be reflected from its surface
simultaneously. If the difference in path of the reflected waves is commensurable
with the maximum frequency of the video signals, phase distortions which cannot
be corrected will occur. For example, if we consider that the average difference
in levels of the moon's surface is 6 km, the path difference in the reflected
rays will correspond to a time difference of 2×10^{-5} seconds. The time required
for scanning one line is equal to 6.4×10^{-5} seconds. Thus, these values are of
the same order of magnitude. Interference of the reflected waves could con-
ceivably reduce the total signal received to zero. Thus, the long way via the
moon is not the shortest way to the solution of this problem.

In all the plans considered thus far for solving the distance problem, a
at[illegible] artificially increasing the operating range of the television trans-
mitter has been advanced but no consideration has been given to the process of
obtaining the picture signals.

A quite detailed treatment of methods for compressing the band of frequen-
cies in the picture signals has recently appeared in the foreign press. This
would make it possible to use a carrier in the short-wave or even in the medium-
wave band. Such a method was first suggested in 1933 by A. P. Konstantinov,
a Soviet physicist.

In calculating the maximum frequency of the picture signals, one usually
assumes that the picture is similar to a chessboard with the linear dimensions
of each square equal in size to a raster element. Actually, such pictures are
rarely encountered. Most of the time, the picture consists of a large number
of details of average size, a smaller number of large details, and a still
smaller number of fine details. The desirability of reproducing all these de-
tails on the television screen forces one to calculate the width of the communi-
cations channel so that all signals can pass through it, even those of very high
frequency arising in the transmission of small details. On the other hand, the
bandwidth could be reduced considerably if the frequencies characterizing the
fine details were not transmitted.

Thus, we must fulfill two mutually exclusive requirements, i.e., we must
expand the frequency band to obtain a high-quality picture and yet we must com-
press the band by reducing the maximum frequency of the picture signals in order
to increase the operating range of the television transmitter. An escape from
this dilemma was found by A. P. Konstantinov. In analyzing the type of pictures
transmitted, he concluded that a new type of scanning had to be developed in
which the reproduction of fine details would not require the transmission of sig-
nals with very high frequency along the communications channel. With this in
mind, Konstantinov suggested that the ordinary linear scan be replaced by a non-
linear scan.

In a linear scan, the electron beam passes along all the details of the pic-
ture with the same velocity; thus, the fine details give short signals, and the
large details, long signals. In the nonlinear scan proposed by Konstantinov,
the electron beam would pass over the large details with a high velocity and over

the fine details with a lower velocity. As a result, the duration of the pulses corresponding to fine details would be increased and the spectrum of frequencies required for the transmission of these pulses would be reduced (Figure 5).

By methods of statistical analysis of the picture signals, it has been shown that it is theoretically possible to compress the band of television frequencies many-fold. A report on this problem was submitted at the May Session of VNORiE by S. I. Borovitchiy. For example, a 60-kc band of frequencies might be transmitted through the communications channel instead of 6 Mc. Such a band could easily be transmitted on wave lengths of the order of 50-100 m.

As seen from the above presentation, the most feasible method for rapid solution of the distance problem in television is that of radio relay networks. This method invites the attractive feature of having Dosaaf clubs build local radio relay installations to provide reliable reception of the Moscow Television Center and other television centers at points remote from them. This would open up a fruitful field of activity for radio amateurs.

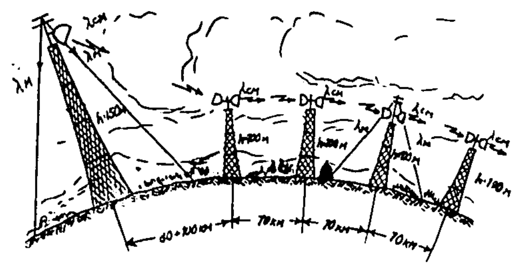

Figure 1. Principle of Operation of a Radio Relay Line Used for Television Transmission

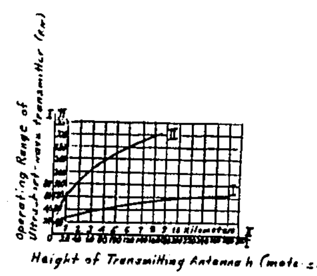

Figure 2. Graph of Operating Radius of an Ultra-short-Wave Transmitter Versus Height of the Transmitting Antenna for a Fixed Height of the Receiving Antenna. The Lower Curve (I) Shows Change of h_1 from 0 to 300 m and the Upper Curve (II), from 1,000 to 10,000 m

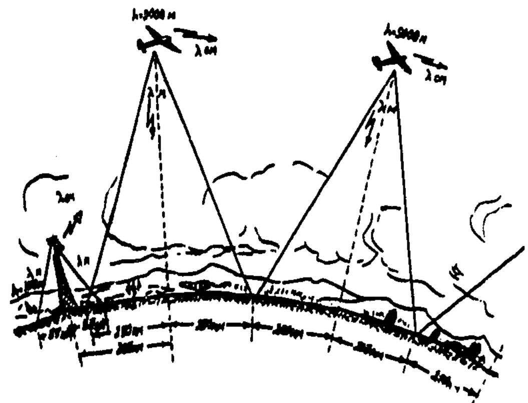

Figure 3. P. V. Shmakov's System for Television Relaying With the Help of Radio Relay Stations Installed on Aircraft

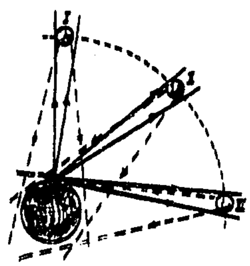

Figure 4. Path of a Television Signal Reflected From the Moon in Three Different Positions

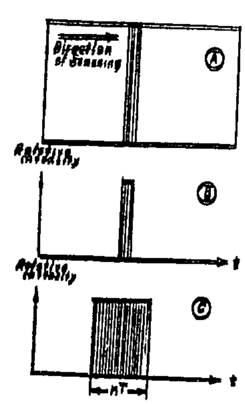

Figure 5. Change in the Duration of the Picture Signal Effected by Nonlinear Scanning: (A) Transmitted Picture, (B) Form of the Signal in Linear Scanning, (C) Form of the Signal in Nonlinear Scanning

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